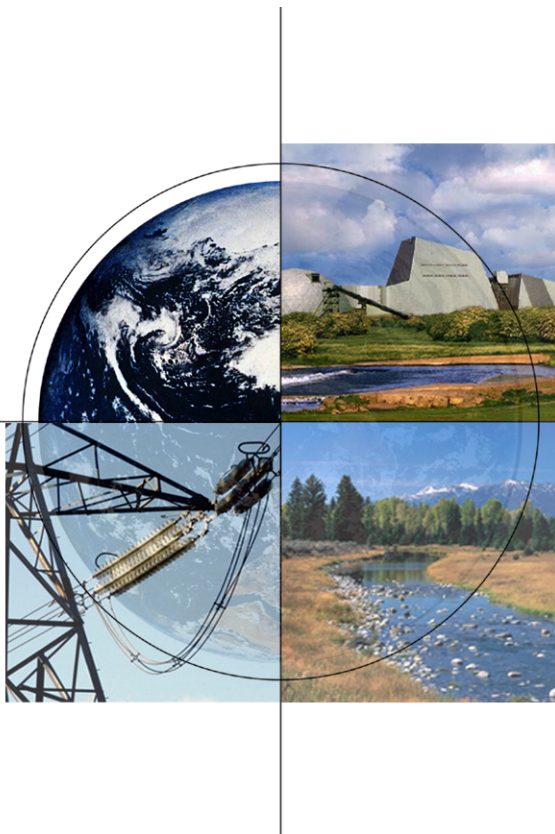


# Bridging the Gap Between Carbon Sequestration Science and Engineering



*Second Annual Conference  
on Carbon Sequestration*

*May 8, 2003*

*Rita A. Bajura, Director*

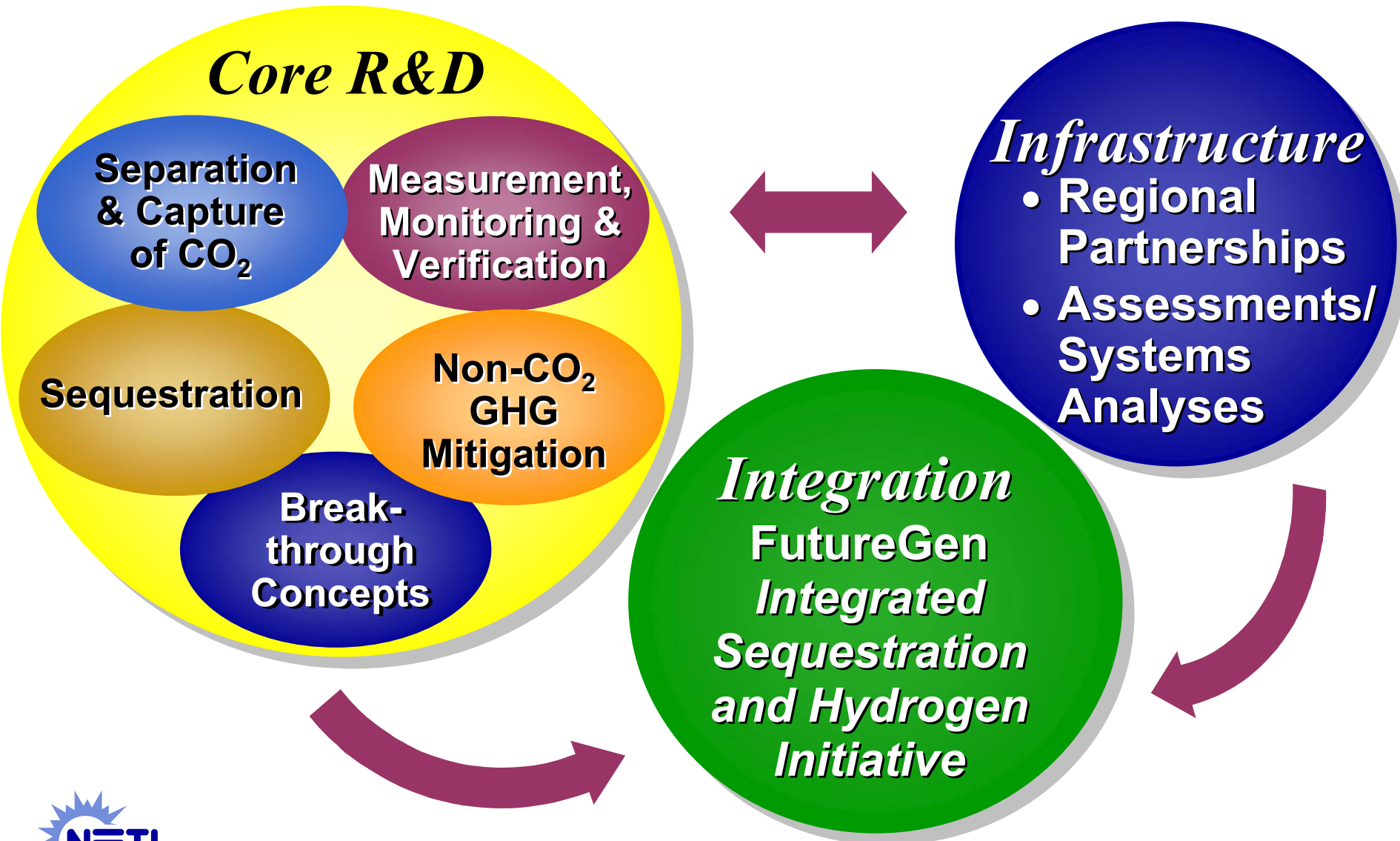
**National Energy Technology Laboratory**



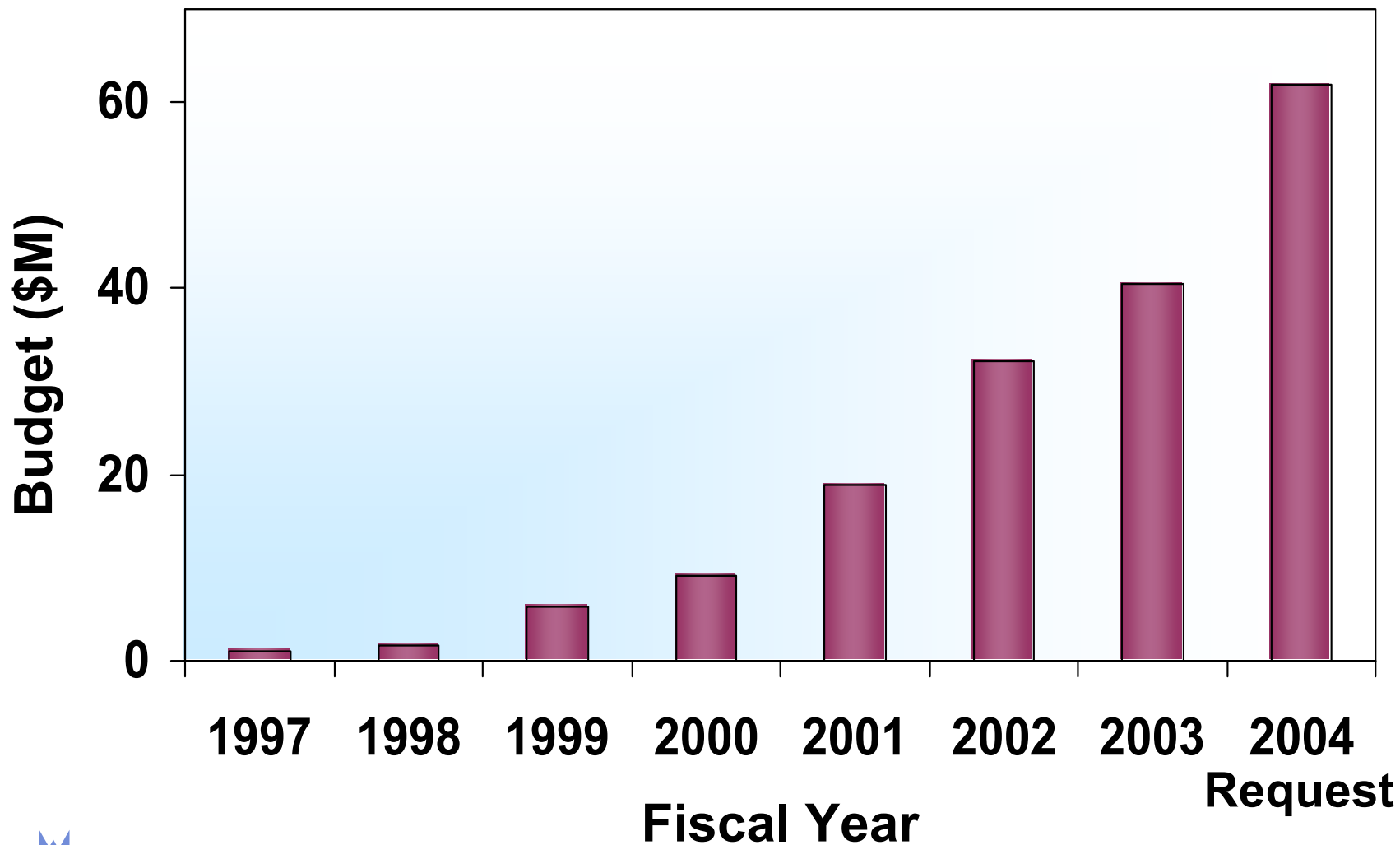
**Office of Fossil Energy**



# DOE Office of Fossil Energy Sequestration Program



# FE Sequestration Program Funding



# FE Sequestration Program Goals

- **By 2012, provide commercially ready options with:**
  - < 10% increase in cost of energy services
  - < \$10 per tonne CO<sub>2</sub> avoided
- **Establish measurement, monitoring & verification protocols**
- **Contribute to Administration's goal of reducing GHG intensity by 18% by 2012**



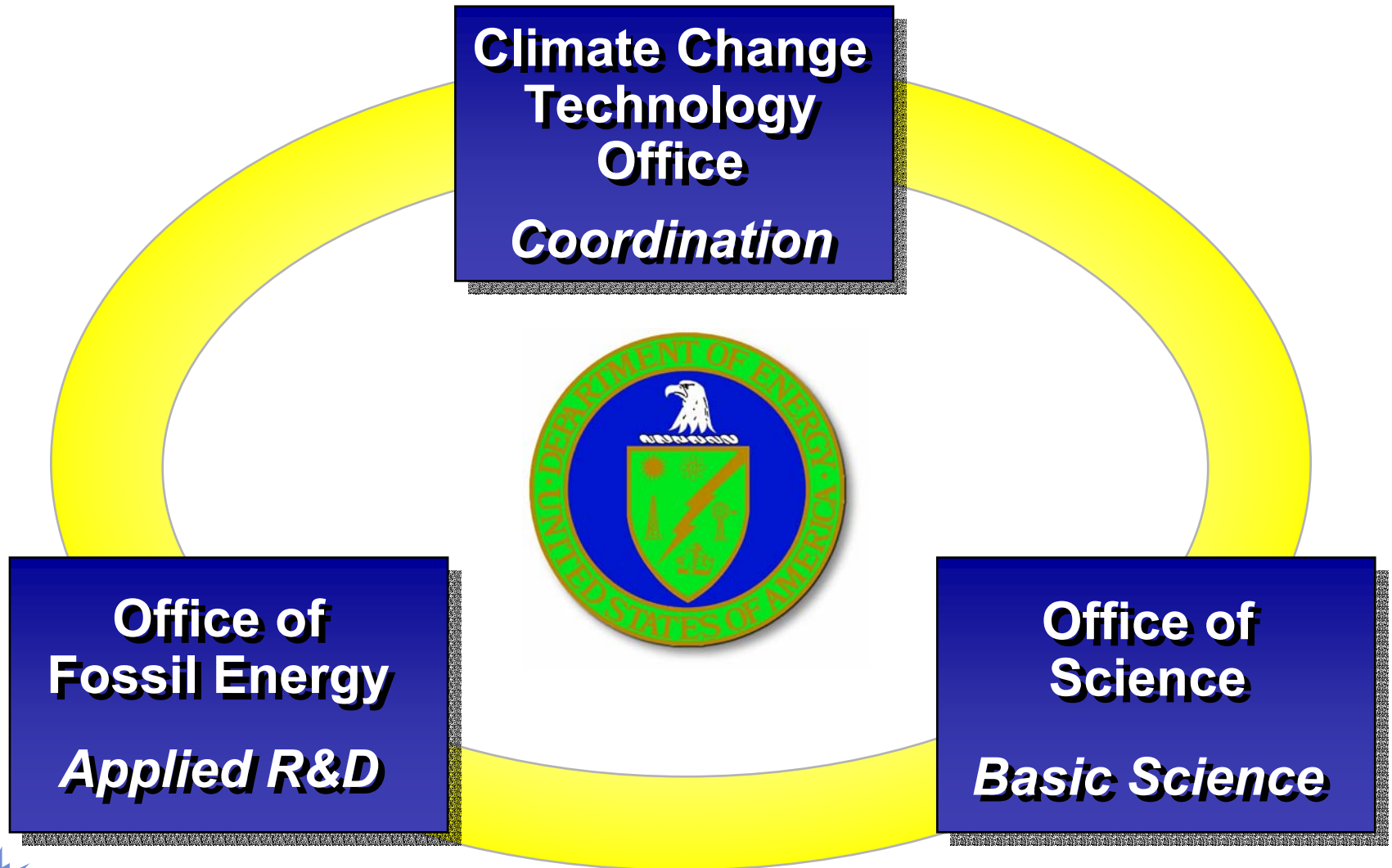
# **DOE's Office of Science Carbon Sequestration Research Programs**

- **Enhancing the natural terrestrial cycle**
- **Carbon sequestration in the ocean**
- **Microbial genome research**
- **Sequestering carbon in underground geologic formations**

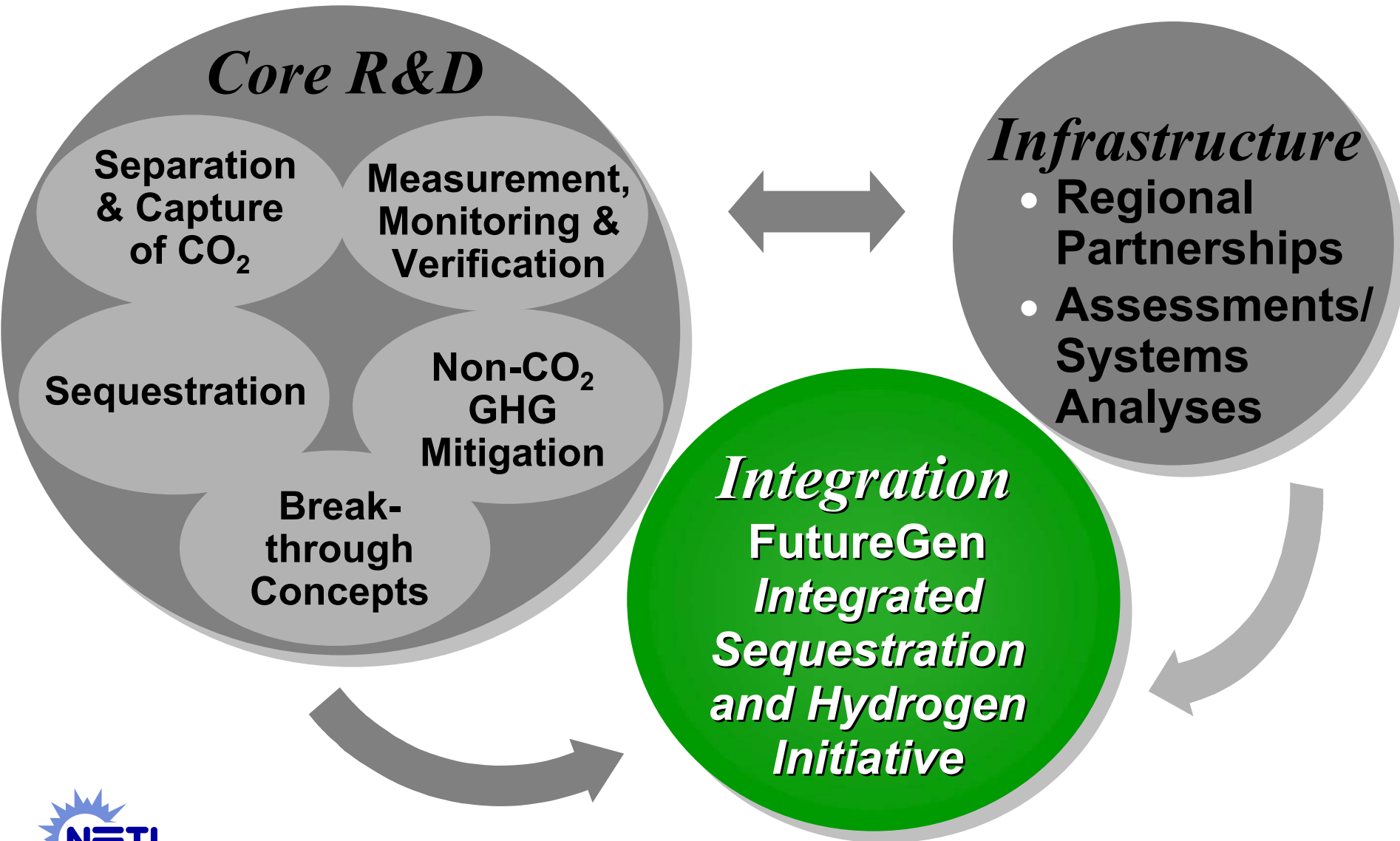
***Science-Based Solutions for  
Mitigating Global Climate Change***



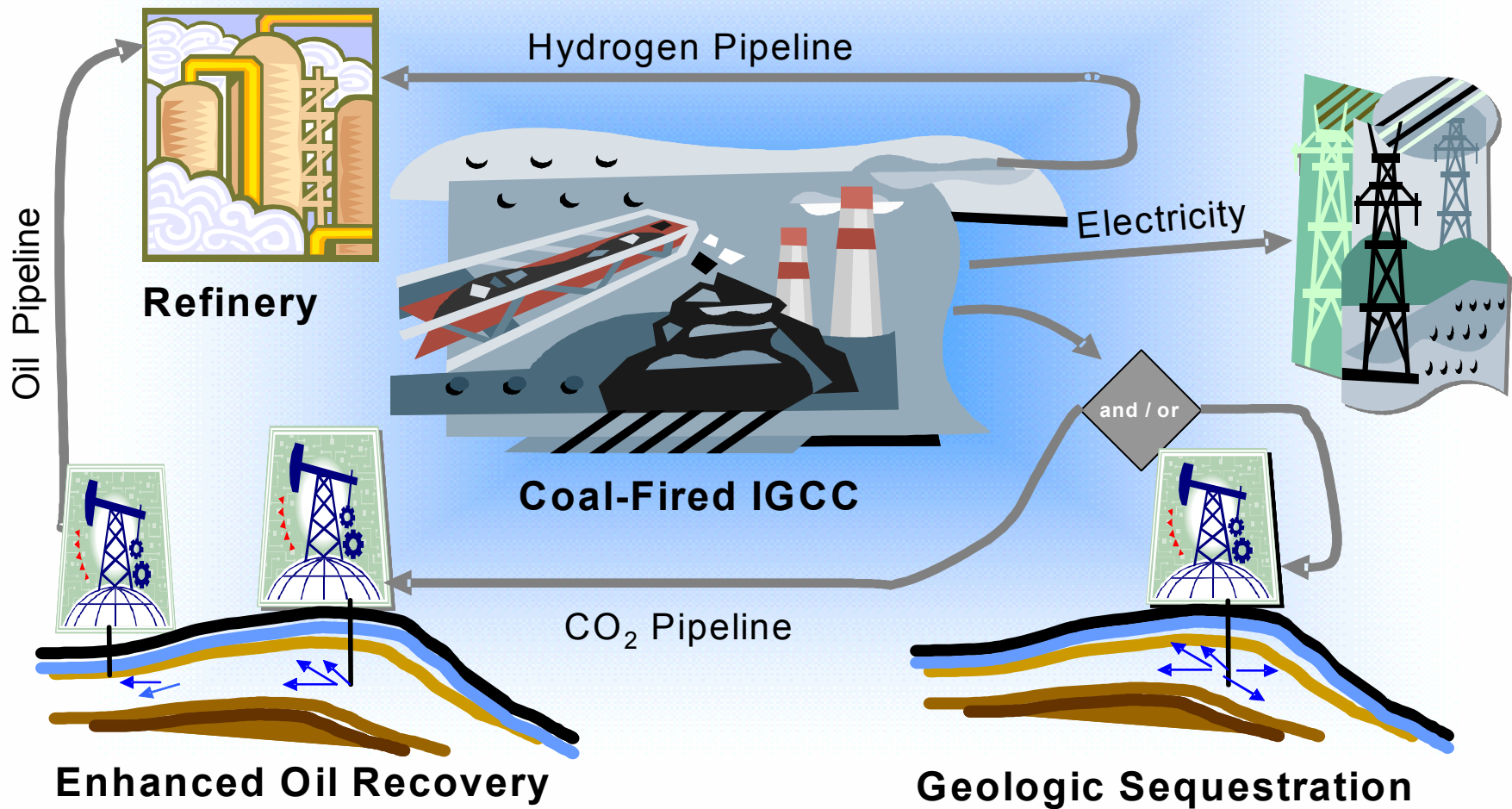
# Sequestration at DOE



# DOE Office of Fossil Energy Sequestration Program



# FutureGen Concept





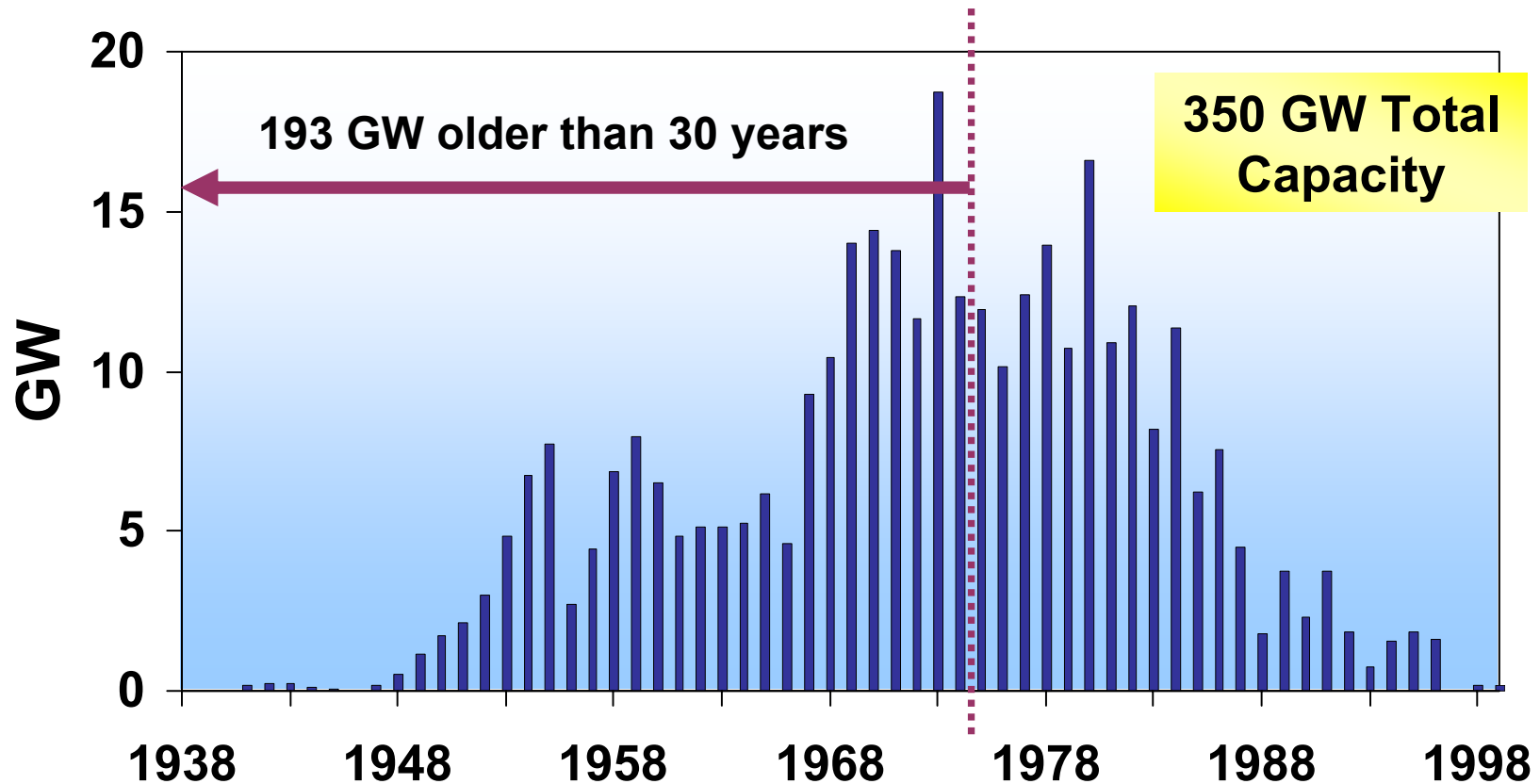
# Why an Integrated Demo?

- **Verify integrated operation at commercial scale**
- **Provide definitive environmental, performance, and cost data to help make rational policy, regulatory, and investment decisions**



# North American Coal Units

## *First Year of Operation*



Many coal plants will need to be replaced or repowered starting in 2020

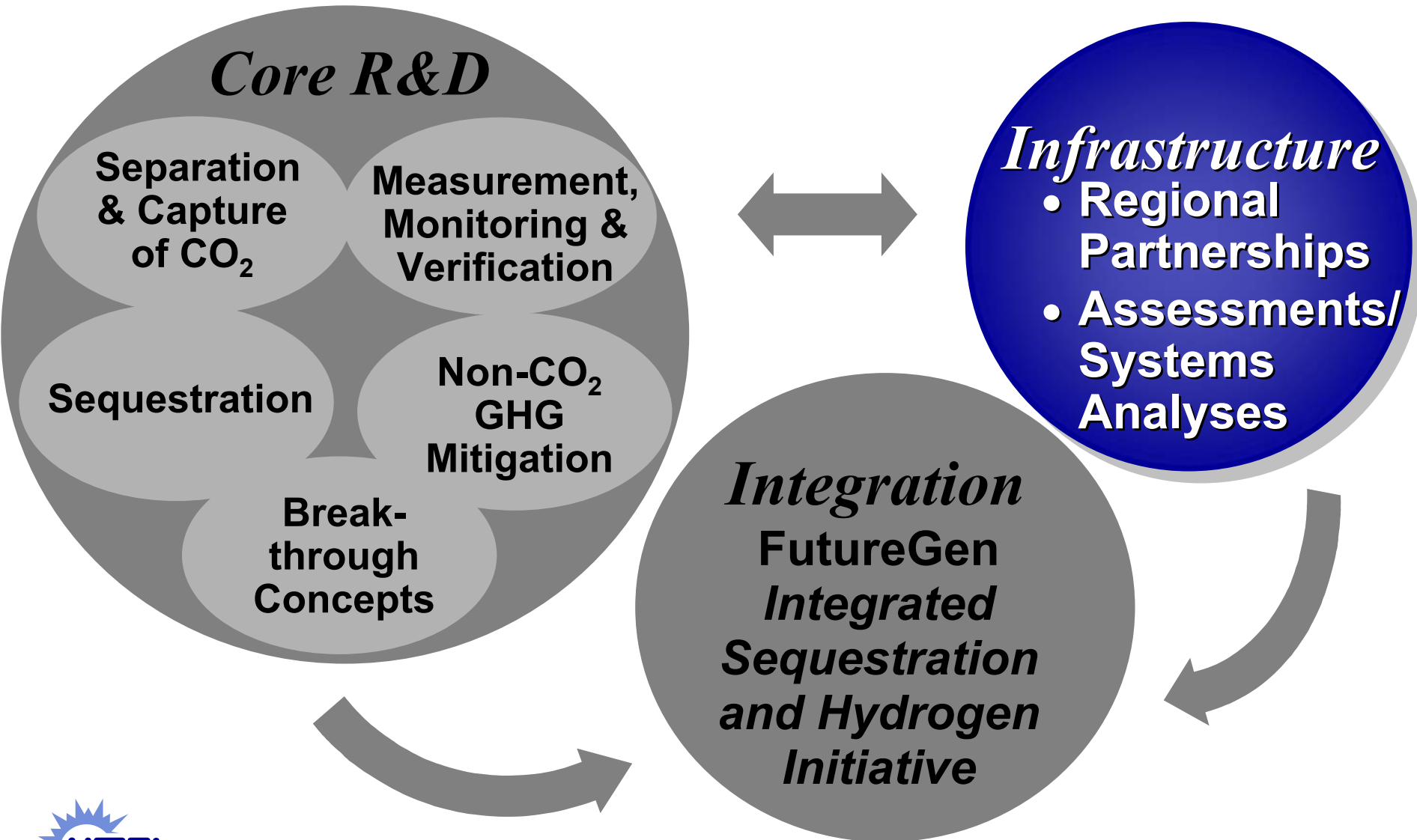
# Window of Opportunity

- Opportunity to deploy near-zero emission coal technologies after 2020
- Construction decisions need to be made starting 2015



**We need to act now to provide the definitive data to help make rational decisions in next 10 to 15 years**

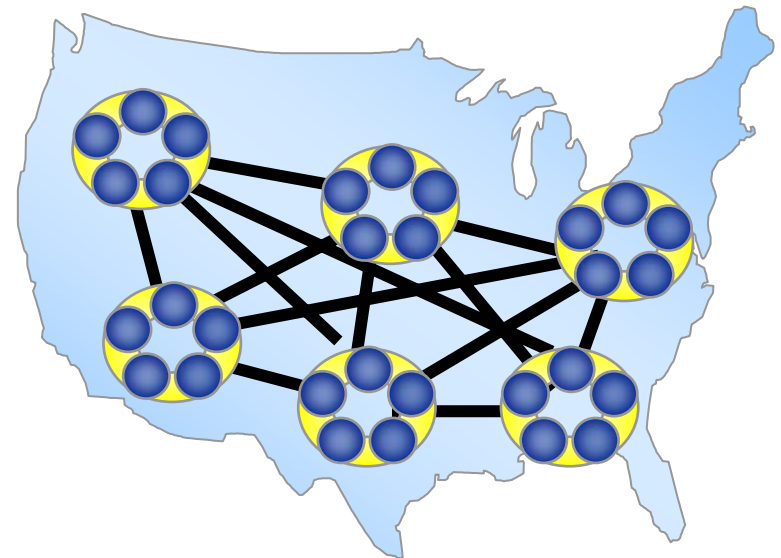
# DOE Office of Fossil Energy Sequestration Program



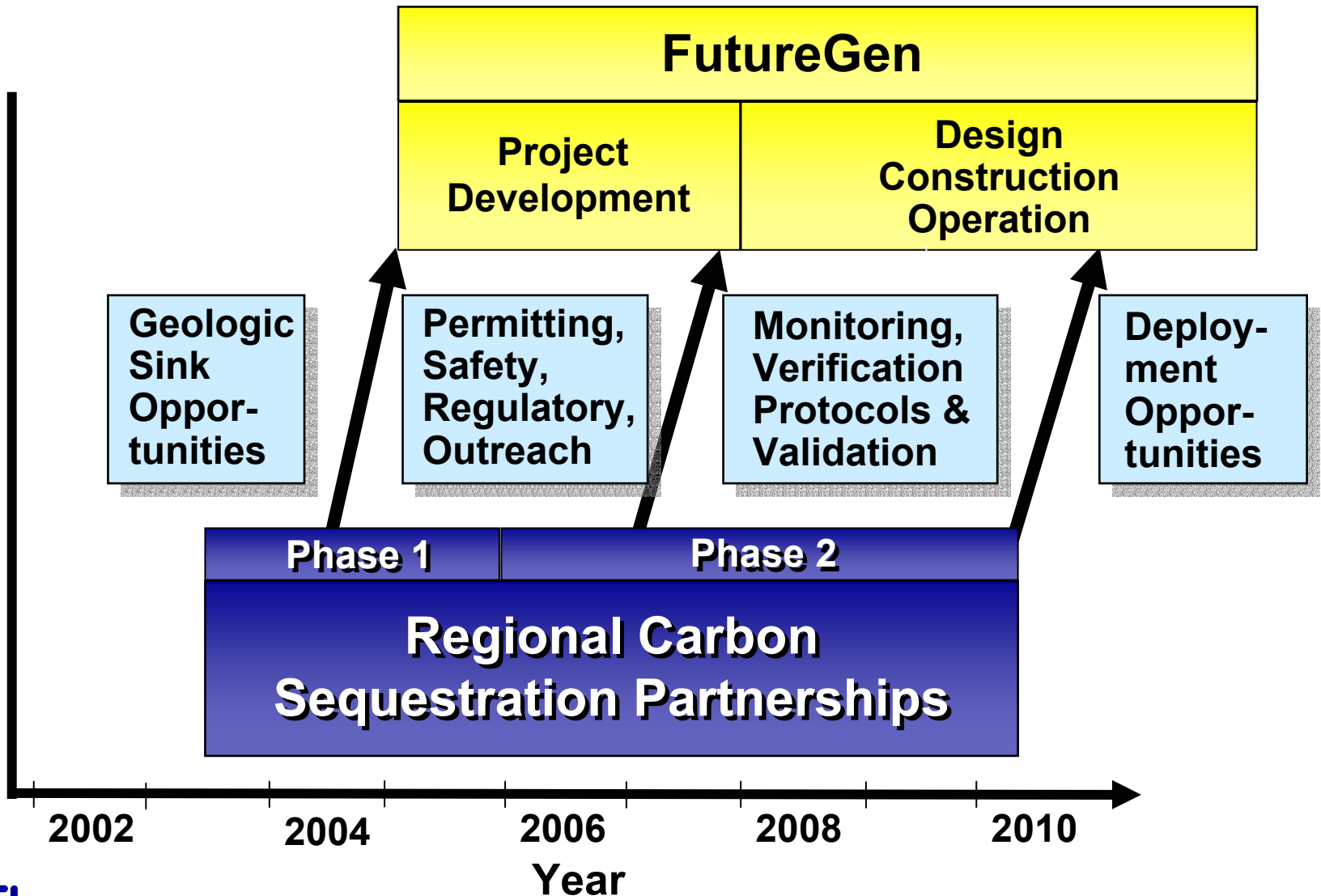
# Regional Carbon Sequestration Partnerships

## *Industry, Universities, and Regional, State & Local Governments*

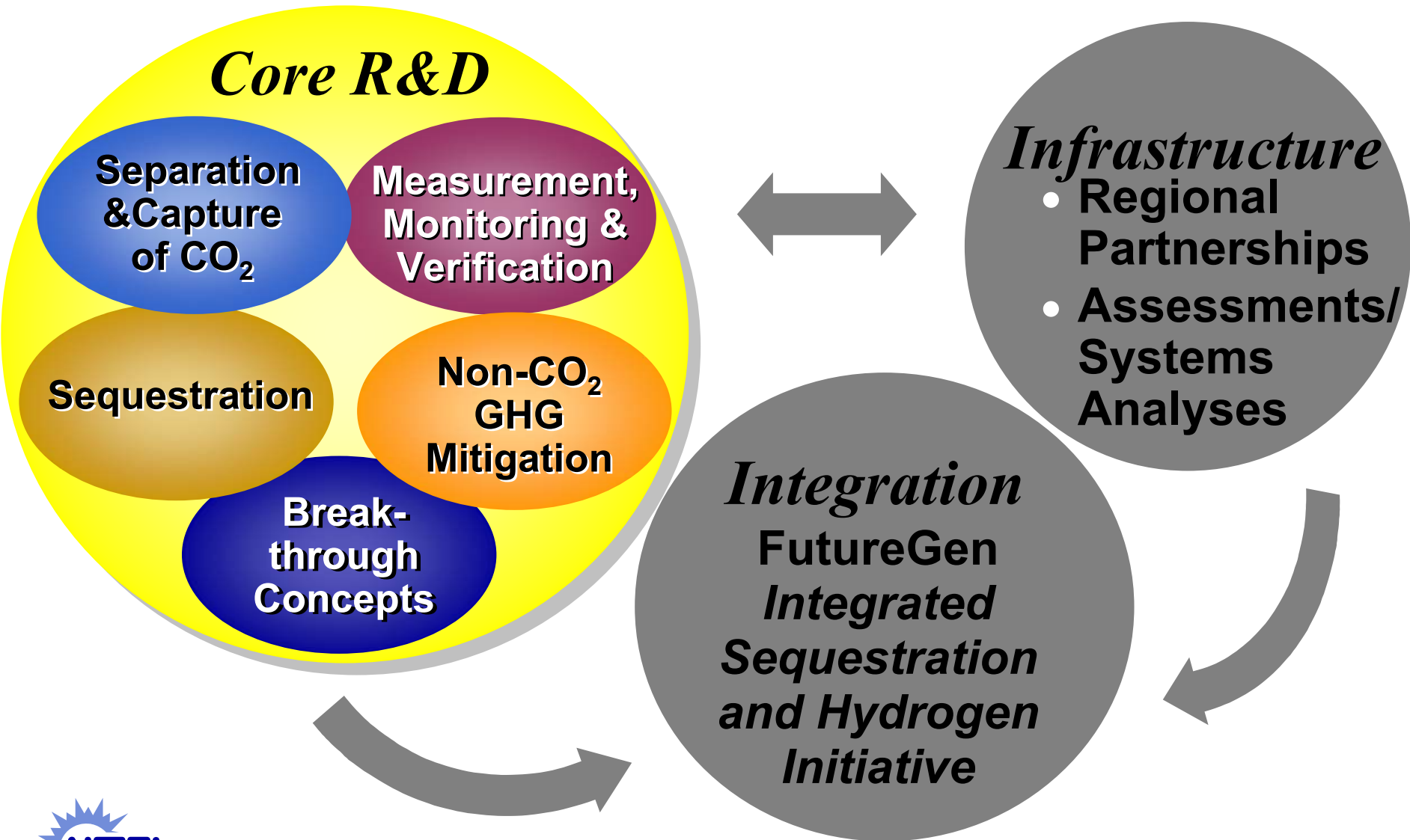
- **Baseline region for sources and sinks**
- **Address regulatory, environmental, outreach issues**
- **Establish monitoring and verification protocols**
- **Test sequestration technology at small scale**
  - Phase 1 - design
  - Phase 2 - testing
- **Determine benefits of sequestration to region**



# Synergies

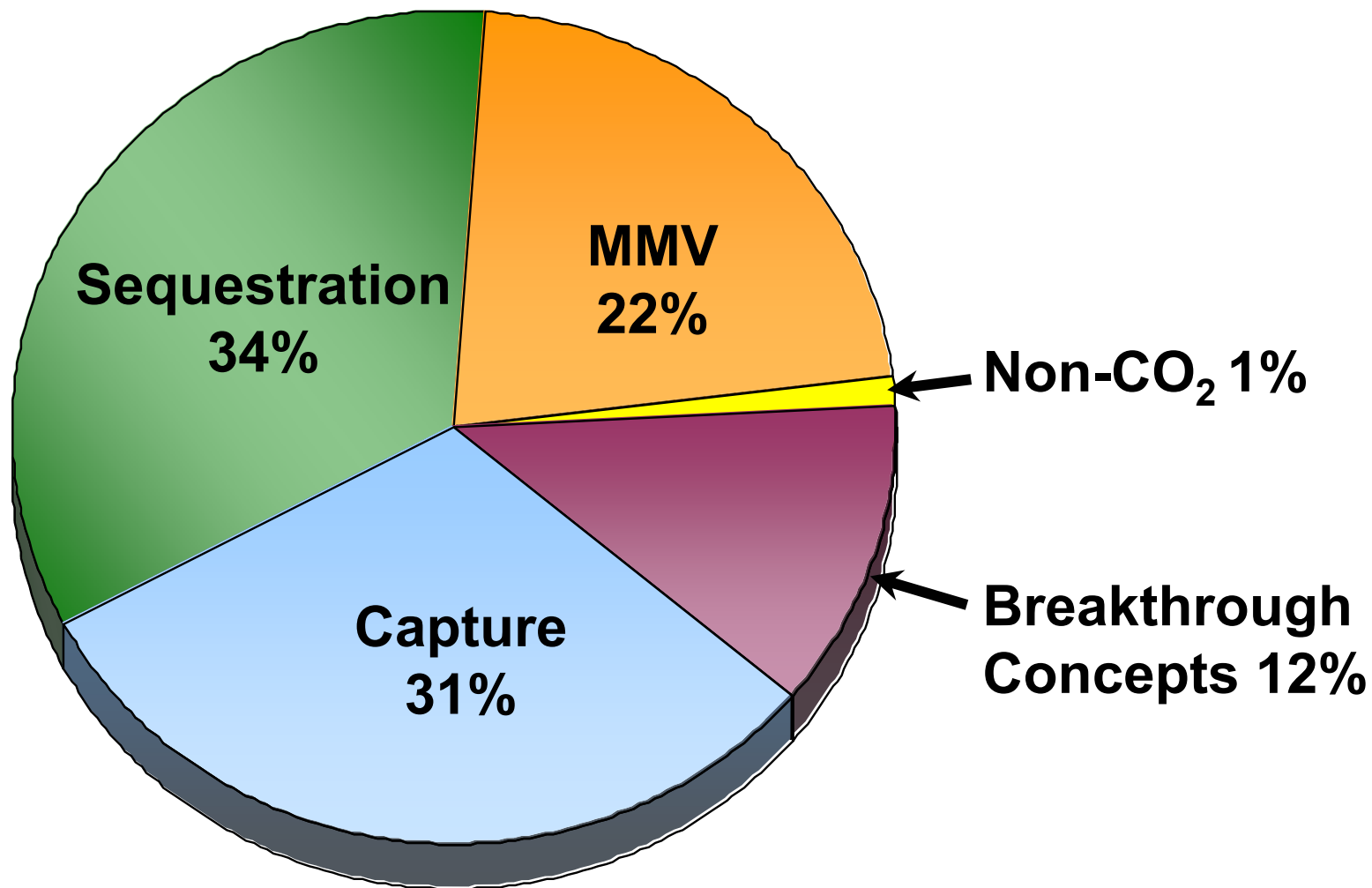


# DOE Office of Fossil Energy Sequestration Program



# Funding Allocation

## *FY 2002 Core R&D Portfolio*





# Issues: *Separation & Capture of CO<sub>2</sub>*

## *Increased*

- Capital cost (30 to 100%)
- Operating cost (25 to 100%)
- Parasitic power loss (5 to 30%)

## *Decreased*

- Plant efficiency (< 30%)



# Pathways: *Separation & Capture of CO<sub>2</sub>*

- **Pre-combustion decarbonization**
- **Oxygen-fired combustion**
- **Post-combustion capture**
- **Advanced integrated capture systems**
- **Chemical looping**



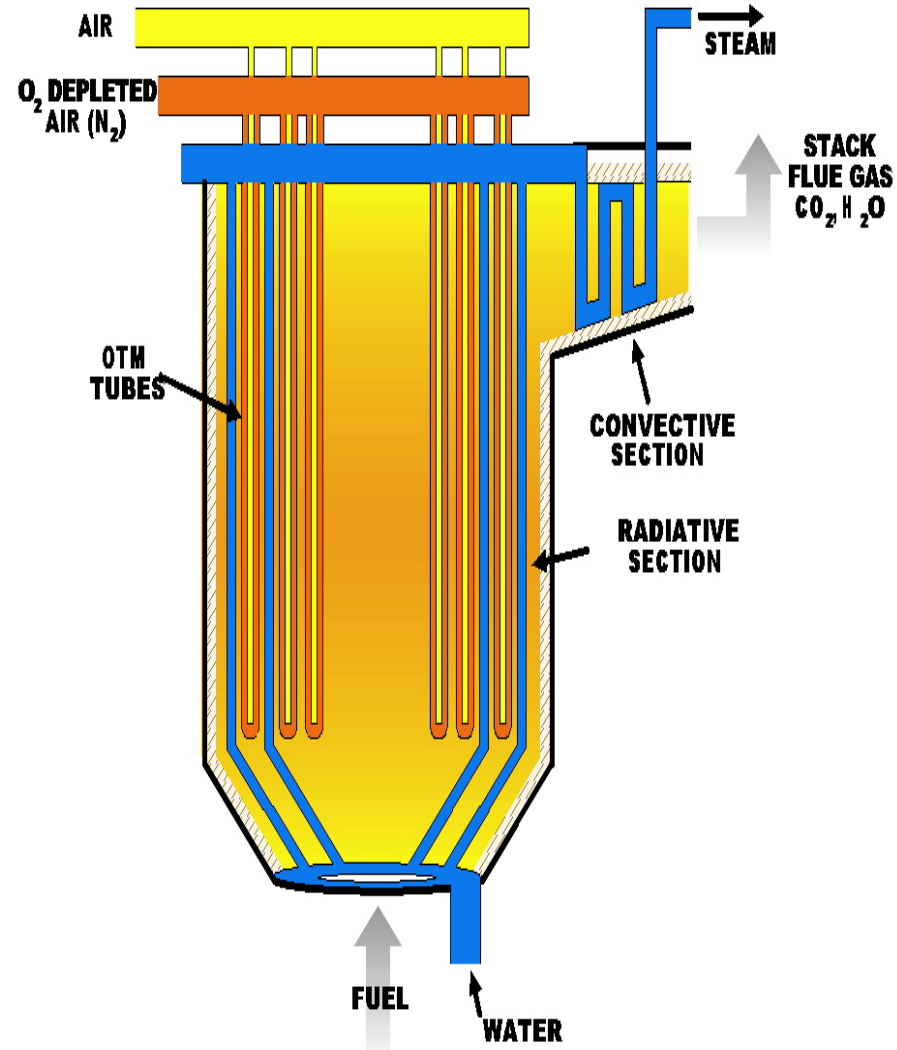
# Oxyfuel Technology

*An advanced boiler that integrates:*

- Air separation using O<sub>2</sub> transport membrane
- O<sub>2</sub> combustion

Participants:

- Praxair
- Alstom Power

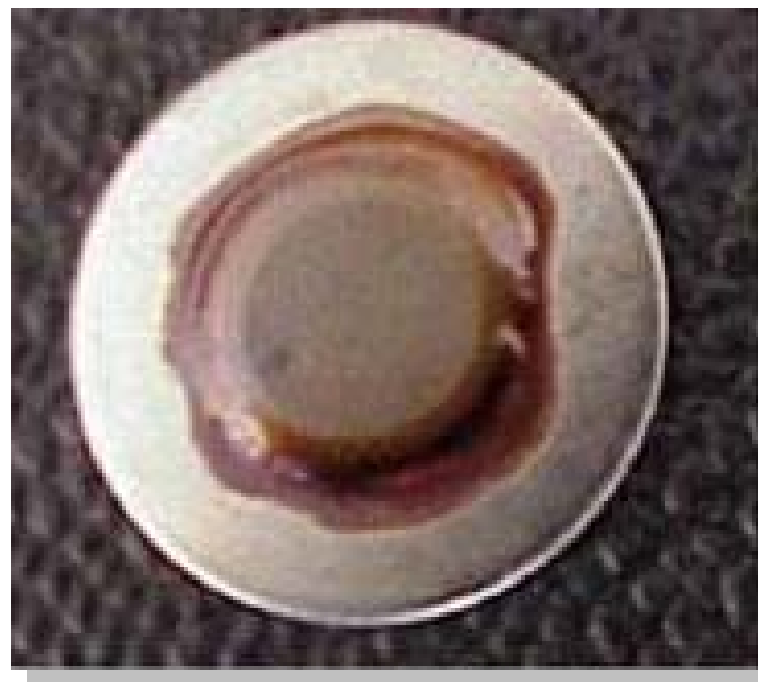


# Thermally Optimized CO<sub>2</sub> Membrane

*CO<sub>2</sub> selective, polymeric-metallic membrane that operates up to 350 °C*

## Participants:

- LANL
- INEEL
- U. of Colorado
- Pall
- Shell



**Polybenzimidazole (PBI)  
Coated Metal**

# Issues: *Sequestration*

- Health, safety, and environmental risks
- Permanence and large-scale verification
- Capacity evaluation
- Infrastructure
- Uncertain regulatory frameworks
- Protocols for identifying amenable storage sites

- Direct CO<sub>2</sub> storage
- Enhanced natural sinks



# Pathways: *Sequestration*

- Underlying science
- Field experiments
- Demonstration projects
- Regional Partnerships



# First U.S. Depleted Reservoir Storage Project

*Track CO<sub>2</sub> plume from  
2,100 ton CO<sub>2</sub> injection*

## Participants:

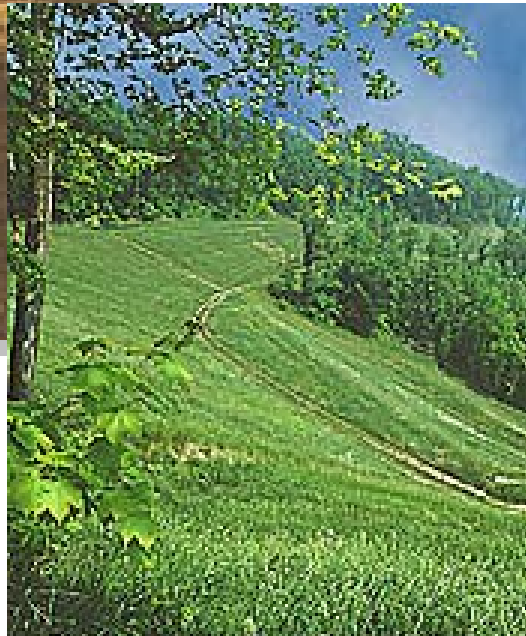
- Strata
- Pecos
- NM Tech
- Sandia
- LANL
- NETL



# Terrestrial Sequestration on Mined Land



***Reforest 650 acres of  
unproductive mine lands***



**Participants:**

- VPI
- U. of Kentucky



# Issues: *Measurement, Monitoring & Verification*

- Surface leakage detection tools
- Improved subsurface assessment tools
- Protocols for accounting & certifying permanence

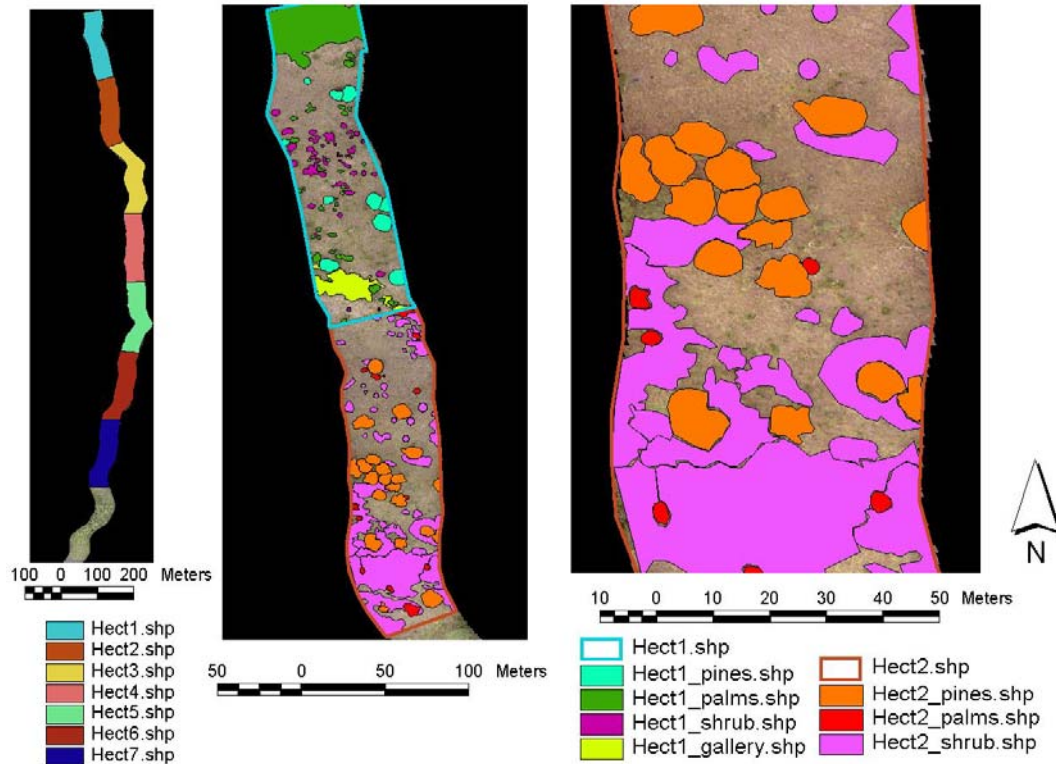


# Pathways: *Measurement, Monitoring & Verification*

- **Atmospheric detection systems**
- **4-D seismic for subsurface detection**
- **CO<sub>2</sub> fate & transport models**
- **Regional Partnerships**



# Remote Monitoring of Terrestrial Sequestration



*Advanced videography  
for aerial-based  
estimation of carbon in  
vegetation & soil*

## ***Participants:***

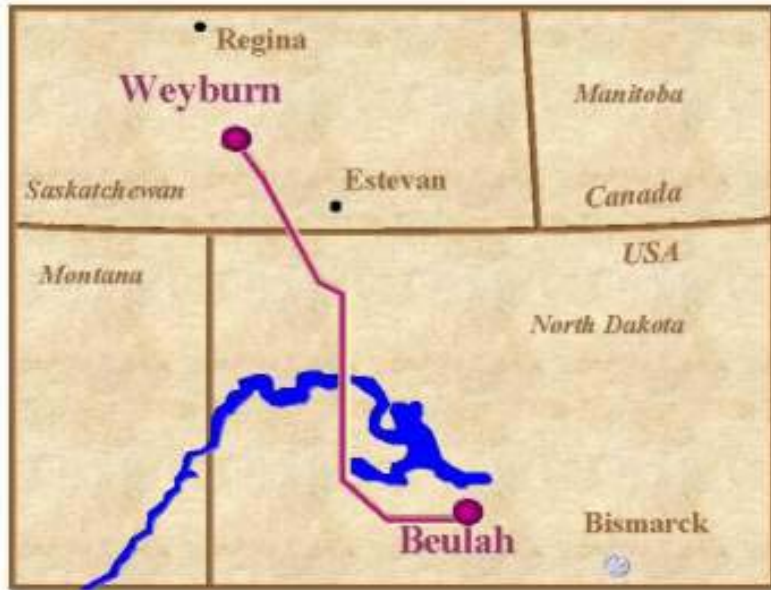
- ***Nature Conservancy***
- ***Winrock International Institute***



*Advanced Videography results shown are from  
Rio Bravo Project in Belize on the Pine Savanna*

# Weyburn Enhanced Oil Recovery Project

***Sequester 1 MMT CO<sub>2</sub> per year from Dakota Gasification Plant***



## Participants:

- CanMet
- Pan Canadian
- IEA GHG Programme



# Issues: *Non-CO<sub>2</sub> Greenhouse Gases*

- Emissions sources are widely dispersed and in many sectors
- Ownership / regulatory uncertainty



# Pathways: *Non-CO<sub>2</sub> Greenhouse Gases*

- **Develop technologies to tap economic value of fugitive methane emissions**
  - Coalbeds
  - Landfills
- **Collaborate with EPA to develop best practice mitigation options**





# Capture & Use Mine Mouth Ventilation Air

*Demonstrate “thermal flow reversal reactor” at commercial scale*

Participants:

- CONSOL
- MEGTEC



# Issues: *Breakthrough Concepts*

- Revolutionary approaches
- Leapfrog cost reductions





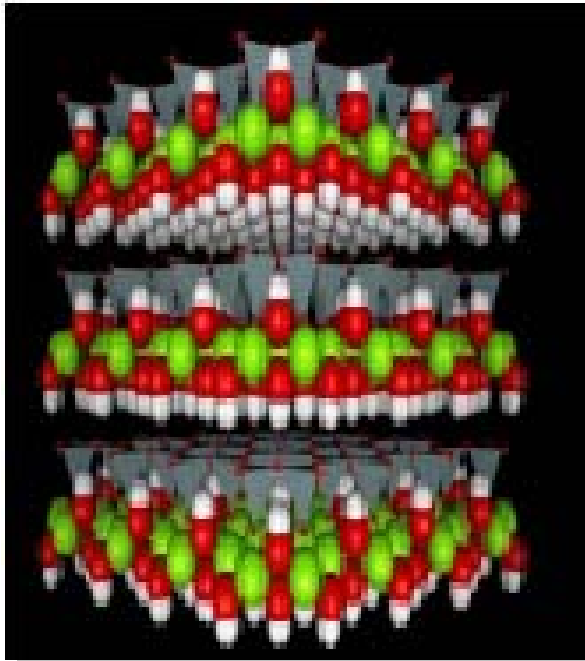
# Pathways: *Breakthrough Concepts*

- **Advanced capture concepts**
- **Advanced chemical reaction pathways**
- **Biogeochemical processes**
- **Novel integrated systems**
- **Subsurface conversion**



# CO<sub>2</sub> Mineralization

*CO<sub>2</sub> reacts with minerals to form stable, solid carbonates*



**Atomic Surpentine Structure**

## Participants:

- Albany
- ASU
- LANL
- NETL



**Bench-Scale Flow Loop Reactor**

# Future Direction for Breakthrough Concepts

- **National Academy of Sciences “beating bushes” for ideas**
  - Workshop targeting universities / small business held in February 2003
- **Issuing solicitation FY 04**
  - Planned FY 04 funding of \$1–2 million



# Why Sequestration?

- Needed to meet energy supply and climate objectives
- Compatible with existing energy infrastructures
- May prove to be lowest cost option

